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EPA-REGION 10

DREDGE PRODUCTION ESTIMATE REVIEW
APPENDIX G of the JUNE 2016 PORTLAND HARBOR FS

INTRODUCTION

The following is a review of the dredge production estimates in Appendix G of the June 2016 Portland Harbor FS (U.S. EPA, June 2016). The review, prepared by Dalton, Olmsted & Fuglevand, Inc. (DOF) is based on DOF's experience at implementing large-scale sediment remediation projects in the Pacific Northwest.

SUMMARY OF DREDGE PRODUCTION RATE ESTIMATES

Two estimates of dredge production rates are presented in Appendix G of the June 2016 PHSS FS in the section titled Cost Estimate Backup, EPA-Derived MII Costs, as prepared by CDM Smith:

- Open Water Dredging – Clam Shell (derrick or crane barge), page 10: 2,382 CY / day
- Confined Area Dredging - Barge Mounted Excavator, page 11: 1,190 CY / day

As described below, a reasonable estimate of dredge production per dredge day (operating two shifts per day) based on DOF's sediment remediation dredging experience in the Pacific Northwest is 1,870 CY/day/dredge for open water dredging with a derrick and clam shell bucket, and 1,060 CY/day/dredge for a barge mounted excavator (Table 1). The DOF production rate estimate for open water dredging with a derrick / clam shell is lower than the Appendix G estimate, while the DOF production rate estimate for the excavator dredge is nearly the same as the Appendix G¹ estimate.

Based on the DOF dredge production rates, the duration of open-water dredging for Alternative I (1,556,599 CY), would increase from 3.1 construction seasons (July-October) for the Appendix G estimate to 4.1 construction seasons, a roughly one-third increase in dredging duration with an expected proportional increase in dredging costs.

The stated production rates do not account for many site factors in Portland Harbor that will complicate the dredging process and further reduce production rates. Nor do they account for the uncertainty regarding the capability of a landfill transload-transport-disposal (TTD) operation to support both the average and peak dredge material production implied by the production calculations.

MECHANICAL DREDGING PRODUCTION FACTORS

The primary components of a production estimate for mechanical dredging are:

- Dredge Production per Hour
- Dredging Time (Effective Working Time)

¹ There are two different excavator production estimates presented in the Cost Estimate Backup of Appendix G. Page 1 states 713 CY/shift, while Page 11 states 595 CY/shift. 595 CY/shift is used as the Appendix G production estimate for this review.

Dredge Production per Hour

The dredge production per hour is based on the following parameters.

- **Bucket Size:** This is the volume capacity of the dredge bucket, expressed in cubic yards (CY). The bucket sizes presented in the Appendix G estimate, 10 CY for a derrick/clam shell dredge and 4 CY for an excavator dredge, are also used in the DOF estimate.
- **Fill Factor (FF):** This is the average volume of material captured in the dredge bucket for each bucket cycle over the course of a project, expressed as a percentage of the Bucket Size. Controlling the fill factor is a primary component of controlling the release and residuals during sediment remediation dredging, as well as the total cost of dredge and disposal. Overfilling of the bucket results in greater environmental releases and residuals. Overfilling of the bucket can also lead to over penetration of the dredge bucket which leads to increased dredge volume and increased cost of dredged material disposal². Because much of the PHSS dredging is outside of the navigation channel, because of the importance of limiting releases / resuspension / residuals from dredging, and because of the high cost of dredged material disposal, the DOF estimate is based on 50% fill factors, as compared to the 60% and 55% fill factors used in Appendix G for a derrick clam shell dredge and excavator dredge respectively.
- **Bucket Cycle Time.** This is the average time, expressed in minutes, for the dredge to complete one cycle of dredging, consisting of lowering the bucket to the river bed, positioning the bucket horizontally for appropriate overlap with the prior bucket placement, positioning the bucket vertically to achieve the desired cut elevation without excess over-depth dredging, raising the bucket up through the water and into the air, swinging the bucket to the material barge, placing the material within the barge and returning to its starting position. For sediment remediation dredging, the bucket cycle time can be on the order of 1 to 2 minutes. Based on our experience, DOF is using a 1.75 minute cycle time for derrick / clam shell dredging, and a 1.25 minute cycle time for excavator dredging, both of which are a bit quicker than the cycle times in Appendix G (2.45 min. for derrick and 1.5 min. for excavator).

The bucket cycle time is used to estimate the bucket cycles per hour by dividing the cycle time into 60 minutes. A 1.25 minute cycle time yields 48 bucket cycles per effective hour. A 1.75 minute cycle time yields 34 bucket cycles per effective hour.

² The estimated cost per cubic yard associated with landfill transport-transload-disposal is nearly eight times more expensive than the estimated cost of the dredging activity in the PHSS Proposed Plan. One way to control overall project costs with such high disposal-related costs is to limit the amount of over dredging below the target removal elevations. While mechanical navigation dredging typically has an allowable overdepth allowance of two feet below the target elevation, sediment remediation mechanical dredging with a derrick and clam shell bucket is more often limited to a foot or less. Constraining the penetration of the dredge bucket to limit over-depth dredging also results in less material being captured in the dredge bucket – resulting in a lower fill factor.

The net production per bucket cycle is equal to the bucket size times the fill factor. For a 10 CY bucket with a 50% fill factor, the net production per cycle would be $10 \times 0.5 = 5$ CY/cycle.

The dredge production rate per uninterrupted hour, referred to as effective working time, is equal to the net production per bucket cycle times the bucket cycles per hour. For a dredge with a 5 CY / cycle net production rate and a 1.75 minute bucket cycle time (34 buckets per hour), the uninterrupted hourly production rate is 170 CY/hr. ($[5 \text{ CY/ bucket cycle}] \times [34 \text{ bucket cycles/hr.}]$). However, as described below, the dredging does not continue uninterrupted throughout a dredging day, reducing the overall dredge production rate.

The Appendix G hourly production estimate also includes two correction factors: Worker Efficiency (90%) and Operator Ability Correction Factor (90%), which reduces the hourly production estimate to 119 CY/hr. for the derrick and 71 CY/hr. for the excavator. The DOF estimate does not use these correction factors, but utilizes more detailed effective working time factors as described below.

Dredging Time

One of the major performance factors affecting schedule and cost for dredging projects is the actual effective time achieved by the dredge on the project. Dredge effective time describes the time when the dredge is generating dredged material, as opposed to non-effective time when the dredging is interrupted and the dredge is not generating dredged material, but rather performing preparatory and ancillary activities. These concepts are defined by the U.S. Army Corps of Engineering (USACE), as summarized below:

- **Effective Working Time (EWT):** "effective working time" is time during the dredging operation when actual material production is taking place.
- **Noneffective Working Time (NEWT):** "noneffective working time" is time during the dredging operation when the dredge is operational but no material production is taking place, such as during times of minor operating repairs, repositioning of the dredge, vessel traffic, and weather.
- **Dredging Time:** "dredging time" is the sum of effective working time, noneffective working time.
- **Percent Effective Working Time (EWT%):** "EWT%" is the ratio of the effective working time to the dredging time, expressed as a percentage.

Dredging Time per week is based on the length of each dredging shift, the number of shifts per day, and the number of work days per week. The DOF estimate of Dredging Time per week is based on two 10-hr shifts per day, six days per week (20/6). The Appendix G estimate is based on two 12-hr. shifts per day, six days per week (24/6). It is DOF's experience that 12 hr. shifts as compared to 10 hr. shifts can result in problematic increases in risks to worker safety and fatigue over the long term, and typically do not show corresponding increases in production due to increased noneffective working time.

Noneffective Working Time (NEWT)

For sediment remediation dredging, NEWT can be divided into two classes: operational time and holding time.

Operational NEWT. This is time spent on normal operational activities of sediment remediation dredging. Examples include:

Stepping – This is relocating the dredge for each dredge set. A dredge set consists of the horizontal distance the dredge can reach sediment at the bottom of the waterway while anchored in place, typically ranging from 20 to 50 feet depending on the dredge and water depth. After completing a dredge set, the dredge is moved ahead or back (stepped) to the next dredge set. Stepping typically happens many times per dredge shift. Stepping typically can take 2 to 5 minutes on average, depending on the nature of the dredging equipment, site conditions and crew experience.

Moving – Mechanical dredging areas are generally divided into parallel dredge lanes, with each lane width on the order of the width of the dredge barge, typically ranging from 40 to 70 feet. Each dredge lane is typically dredged from upstream to downstream, and when the dredging in a dredge lane is completed, the dredge has to be moved back upstream to the start of the next dredge lane. Depending on the site conditions, the dredge plan and effects of changing water levels, the dredge may be moved several times per shift. Moving the dredge to the next dredge lane can take 15 to 20 minutes on average.

Changing Sediment Barge. Mechanical dredges place dredged material into sediment barges that are tied up to the dredge barge. The size of sediment barges typically ranges between 500 and 1,500 tons, depending on the availability of suitable sediment barges in the region at the time of a project. Once a sediment barge is filled, it is removed from the dredge barge by a tug boat and an empty barge is brought alongside the dredge by a tug boat and tied up to the dredge barge so that dredging can continue. Changing sediment barges will happen multiple times per day depending on the size of the sediment barge and the production rate of the dredge and can take 15 to 20 minutes on average, depending on the nature of the dredging equipment, weather, crew experience and availability of moorage or anchoring locations within the project area to moor barges.

Maintenance and Repairs. Maintenance and minor repairs occur on an ongoing basis during dredging, including for example greasing and refueling of equipment or adjusting friction brakes on crane or spuds. In the case of sediment remediation dredging where higher precision is needed to assure removal of the target material without excessive over dredging, there are additional maintenance and repairs associated with GPS-based electronic navigation and bucket positioning systems. These systems involve multiple electronic sensors, some that are submerged with each bucket cycle. On the order of a half-hour may be spent on maintenance and minor repairs each shift for sediment remediation dredging.

Holding NEWT. This is time the dredging is stopped and put on hold for non-operational reasons. Examples include:

Holding for Empty Sediment Barge. Historically, waiting for empty sediment barges at the dredge has been one of the more significant categories of holding times for sediment remediation projects completed by mechanical dredging. The source of the holdup has been the delays in the landfill transload-transport-disposal (TTD) operations of the project. For example in the first year of the Upper Hudson River PCB dredging project (New York), the dredges were shut down for 31% of the available Dredging Time waiting for empty barges due to operational issues at the transload facility and interruptions in rail transport of the dredged material. In recently completed early action dredging on the Duwamish Waterway

(Washington), the dredges were holding for empty sediment barges for 12% of the available dredging time over the course of three dredging seasons. A primary factor for the delays was interruptions in rail service for the transload facility. These rail interruptions can disrupt the normal production cycle for multiple days. If rail service is interrupted and barge offloading stopped, dredging operations quickly cease once all sediment barges are full. Rail service then needs to be restored and barges emptied before dredging can resume.

Holding for River Traffic. Major vessel traffic in the navigation channel of the PHSS consists of ocean-going ships (cargo and container) as well as large barges (petroleum, grain). Ships and barge traffic moving in the navigation channel have the right of way over dredging operations. Consequently a dredge working in the navigation channel has to move out of the way to allow for ship passage. In the case of smaller vessels, there may be sufficient width of the navigation channel to allow passage without moving the dredge. However in the case of deep-draft ocean-going ships and large barges, the dredge may need to move out of the navigation channel to allow for safe passage of the vessel.

The timing of the move out of the navigation channel is coordinated through radio communication between the river pilot of the large ship and the tug captain for the dredge. The duration of NEWT to move the dredge out of the channel while the large ship passes and then back again to the position the dredge occupied can be on the order of a half hour to an hour or more per event. Depending on the frequency of ship movements through the dredge area in the navigation channel, the amount of NEWT for vessel traffic can be significant. An animation of this operation can be viewed at:

<http://dofnw.com/animation>

In addition to NEWT associated with traffic in the navigation channel, the dredge may also have to move periodically to accommodate ship movement to waterfront docks through the Future Maintenance Dredge (FMD) areas. It is likely that necessary coordination of dredging with ongoing operations at waterfront businesses and the associated ship traffic will also reduce the effective working time for the dredge.

Other Holding Time. Depending on site conditions and the time of year for dredging, there are multiple situations that result in additional holding time for the dredge. Examples include holding for crew change, adverse weather, sampling and surveying in the dredge area, others on the river who move into or pass through the work area such as recreational boaters and fishers, and directed standby while unanticipated conditions are evaluated.

In summary, NEWT can run on the order of 40% to 55% of the available dredging time for sediment remediation with upland disposal in an active industrial harbor, which results in EWT% ranging from 45% to 60%. The NEWT tends to be the highest during the first dredging season of a multi-season project, and typically improves each year as project implementation is refined and crew experience working together increases.

Figure 1 presents the compiled dredging times for a 2013-2015 sediment remediation project on the Duwamish Waterway (Seattle) which achieved a composite EWT % of 54%. For the DOF PHSS estimate, the EWT% was assumed to average 55% over the course of the project.

PHSS DREDGE PRODUCTION ESTIMATE

The DOF PHSS dredging production rate for a derrick working in open water is 1,870 CY/ day (two 10-hr. shifts per day at 55% EWT). At this rate the 1,556,599 CY of open-water dredging identified for Alternative I would take an estimated 832 dredging days to complete. Operating two such dredges in tandem would produce an average production of 3,740 CY/day, 380,000 CY/year +/-, and would take an estimated 416 +/- days to complete. Based on a 17 week dredging season (July through October) and a six day per week dredging schedule, it would take an estimated 4.1 years of dredging with two dredges to remove the indicated volume (Table 1). This is approximately one-third longer than the 3.1 years of dredging presented in Appendix G that is based on a production rate of 2,400 CY per dredge per day, or 5000,000 CY/year +/- for two dredges working in tandem.

It cannot be understated that sustaining these estimated dredge production rates will be highly dependent on the capacity of landfill transload-transport-disposal services to both meet a sustained TTD rate at the noted daily average dredge production rate, but also be capable of multiple consecutive-day peak TTD rates on the order of 1.5+ times the daily average dredge production rate. Otherwise, the NEWT will increase and the dredging production will drop.

The stated dredge production estimates do not fully take into account the multiple dredge-limiting site factors that exist in Portland Harbor. Those site factors include, for example: ongoing facility operations along the waterfront that would conflict with dredging operations and result in decreased production, oversteepened shoreline slopes and associated destabilization of slopes by dredging that will cause work stoppages or delays, areas of significant debris buried in the sediment that will interfere with efficient bucket closure which will slow dredge production and contribute to increased releases from dredging, and the presence of numerous groups of historic piling remnants that will interfere with positioning of the dredge and dredge bucket and slow the dredging process.

TABLE 1. PHSS Dredge Production Estimate

PRODUCTION COMPONENT	UNITS	DOF Estimate		Appn. G Estimate	
HOURLY DREDGE PRODUCTION					
Dredge Type		Derrick	Excavator	Derrick	Excavator
Bucket Size	CY	10	4	10	4
Fill Factor	%	50%	50%	60%	55%
Net Bucket Production	CY	5	2	6	2.2
Cycle Time	Min.	1.75	1.25	2.45	1.5
Cycles/Hr.	ea.	34	48	24	40
Hourly Production	CY/Hr.	170	96	147	88
Work Efficiency	%			90%	90%
Operator Correction Factor	%			90%	90%
Adjusted Hourly Prod.	CY/Hr.			119	71
DREDGE PRODUCTION RATES (Note 1)					
Dredge Shift	hrs./shift	10	10	12	12
EWT%	%	55%	55%	83%	83%
EWT Hrs. / Shift	hrs. /shift	5.5	5.5	10	10
Production/Shift (Note 2)	CY/shift	935	528	1191	595
Shifts/Day	ea.	2	2	2	2
Production/Day/Dredge	CY/day	1,870	1,060	2,380	1,190
Weeks/Season	Wk.	17	17	17	17
Days /Season (6-day week)	Day	102	102	104	104
Dredge Prod./Season/Dredge	CY/season	191,000	108,000	248,000	124,000
DREDGE DURATION					
Total Vol. Alt I	CY	1,556,599	93,151	1,556,599	93,151
Production/Day/Dredge	CY/day	1,870	1,060	2,380	1,190
Dredge Days	Day	832	88	650	78
Number of Dredges	ea.	2	1	2	1
Daily Prod. Multiple Dredges	CY/day	3,740	1,060	4,760	1,190
Annual Prod. Multiple Dredge	CY/yr.	382,000	108,000	496,000	124,000
Dredging Seasons	Yr.	4.1	0.9	3.1	0.8

Note 1. Dredge production per day rounded to nearest 10 CY. Dredge production per season rounded to nearest 1,000 CY

Note 2. There are two different excavator production estimates presented in the Cost Estimate Backup of Appendix G. Page 1 states 713 CY/shift, while Page 11 states 595 CY/shift. 595 CY/shift is used as the Appendix G production estimate for this review.

FIGURE 1. SEDIMENT REMEDIATION DREDGING TIMES EXAMPLE

